REMARKS

This paper responds to the final Office action dated October 28, 2009, in which (i) three objections were made to the specification, and (ii) claims 1-20 were rejected under 35 U.S.C. §112, first paragraph.

I. Summary of Amendments

No claims have been added or cancelled by the foregoing amendments, leaving claims 1-20 pending and at issue.

The specification has been amended to remove a sentence regarding moveable flaps from the paragraph starting at page 15, line 2, of the application as filed. The sentence had been added by the applicants' previous response, and was the subject of one of the objections to the specification.

II. Responses to Objections to Specification

Reconsideration and withdrawal of the three objections to the specification are respectfully requested for at least the reasons set forth below. The three objections relate to references to (A) moveable flaps, (B) a closed loop of hydrodynamic force, and (C) decelerated flow relative to a hull, each of which is addressed in turn below.

A. <u>Moveable flaps</u>. The applicants respectfully submit that the foregoing amendments to the specification render this objection moot.

B. <u>Closed loop of hydrodynamic force</u>. The applicants respectfully traverse this objection and submit that the specification provides the requisite antecedent basis for the referenced claim language. The applicants direct attention to the paragraph of the specification starting at page 3, line 23 (labeled paragraph [0003] in the publication of the application), and stating in pertinent part:

> In this way, a keel with an enclosed flow path (or "loop keel" defining a "loop") is provided which, when submerged in water in use, may result in a closed loop of hydrodynamic force, all directed away from (the centre of) the enclosed closed flow path.

The applicants accordingly submit that the antecedent basis requirements of 37 CFR 1.75(d)(1) are satisfied by the express language of the specification.

C. Decelerated flow. The applicants respectfully traverse this objection and submit that the specification provides adequate support for the referenced claim language based on an inherent property of the keel as claimed. Further details in support of the inherency of the decelerated flow are provided below in connection with the rejections of the claims under 35 U.S.C. §112.

III. Responses to Claim Rejections

Claims 1-20 stand rejected under 35 U.S.C. §112, first paragraph, based on the written description requirement for support of the following limitations recited in claim 1: (A) a keel configured to generate a closed loop of hydrodynamic force; and (B) incident flow being decelerated relative to a hull.

Reconsideration and withdrawal of the claim rejections are respectfully requested, insofar as the applicants respectfully submit that the specification as originally filed adequately supports each of the claim limitations for at least the reasons set forth herein.

A. Closed loop of hydrodynamic force. The applicants respectfully submit that the specification as originally filed supports this limitation for the reasons set forth in connection with the corresponding objection to the specification.

The applicants further respectfully note that claim 1 does not recite that the keel has a closed loop, or that the keel is a closed loop structure. Claim 1 instead specifies that the hydrodynamic force generated by the keel forms a closed loop. Whether the keel will produce such a closed loop of hydrodynamic force is a consequence of the hydrodynamic force generating profile of the limbs, as recited in claim 1. As illustrated in Figure 1, for example, the arcuate keel structure of the disclosed embodiment creates such a closed loop of hydrodynamic force. The closed loop is created even though the limbs do not join together to form a ring structure of the type identified in the action.

B. Decelerated flow. The applicants respectfully submit that the specification as originally filed supports this claim limitation, inasmuch as the limitation recites an inherent property or function of the keel as claimed. The incident flow passing through the enclosed flow path is decelerated relative to the hull because, in order to generate hydrodynamic force, a foil must necessarily cause both (i) the fluid flow over the low pressure surface of the foil to accelerate and (ii) the fluid flow over the opposed high pressure surface to decelerate. The

deceleration is a basic principle well known to persons of ordinary skill in the art of fluid mechanics.

The applicants respectfully submit that this principle is covered in elementary textbook explanations of flight. Courtesy copies of excerpts from two well-established and popular science textbooks are attached hereto as Exhibits A and B. The relevant portions of the following excerpts directed to this basic principle of flight have been highlighted:

> **Exhibit A:** Bloomfield, How Everything Works – Making Physics Out of the Ordinary, ISBN 0-471-74817-X, pp. 169-170 (2007) (in the first full paragraph on p. 170, "In contrast, the lower airstream bends primarily away from the wing, so the air's pressure just below the wing is above atmospheric … and its speed is decreased"); and
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> **Exhibit B:** Anderson et al., Understanding Flight, ISBN 0-07-136377-7, pp. 15-17 (2001) (in the paragraph bridging pp. 16 and 17, "In fact, the air that passed under the swing has a somewhat retarded velocity compared to the velocity of air some distance from the wing.").

The applicants respectfully submit that the attached extrinsic evidence makes clear that the claimed subject matter is necessarily present in the keel as claimed, and that the subject matter would be so recognized by persons of ordinary skill. Under MPEP 2163.07(a), it follows that the recitation of claims 1-20 is adequately supported under 35 U.S.C. §112, first paragraph.

IV. Conclusion

For the foregoing reasons, it is submitted that all pending claims 1-20 are in condition for allowance, and an indication to that effect is solicited. Should the examiner wish to discuss the foregoing or any matter of form in an effort to advance this application toward allowance, the examiner is invited to telephone the undersigned at the number below.

Dated: January 26, 2010

Respectfully submitted,

By /G. Christopher Braidwood/

G. Christopher Braidwood, Reg. No. 41,631
LEMPIA BRAIDWOOD LLC
One North LaSalle Street, Suite 3150
Chicago, Illinois 60602
(312) 291-0860
Attorney for Applicant

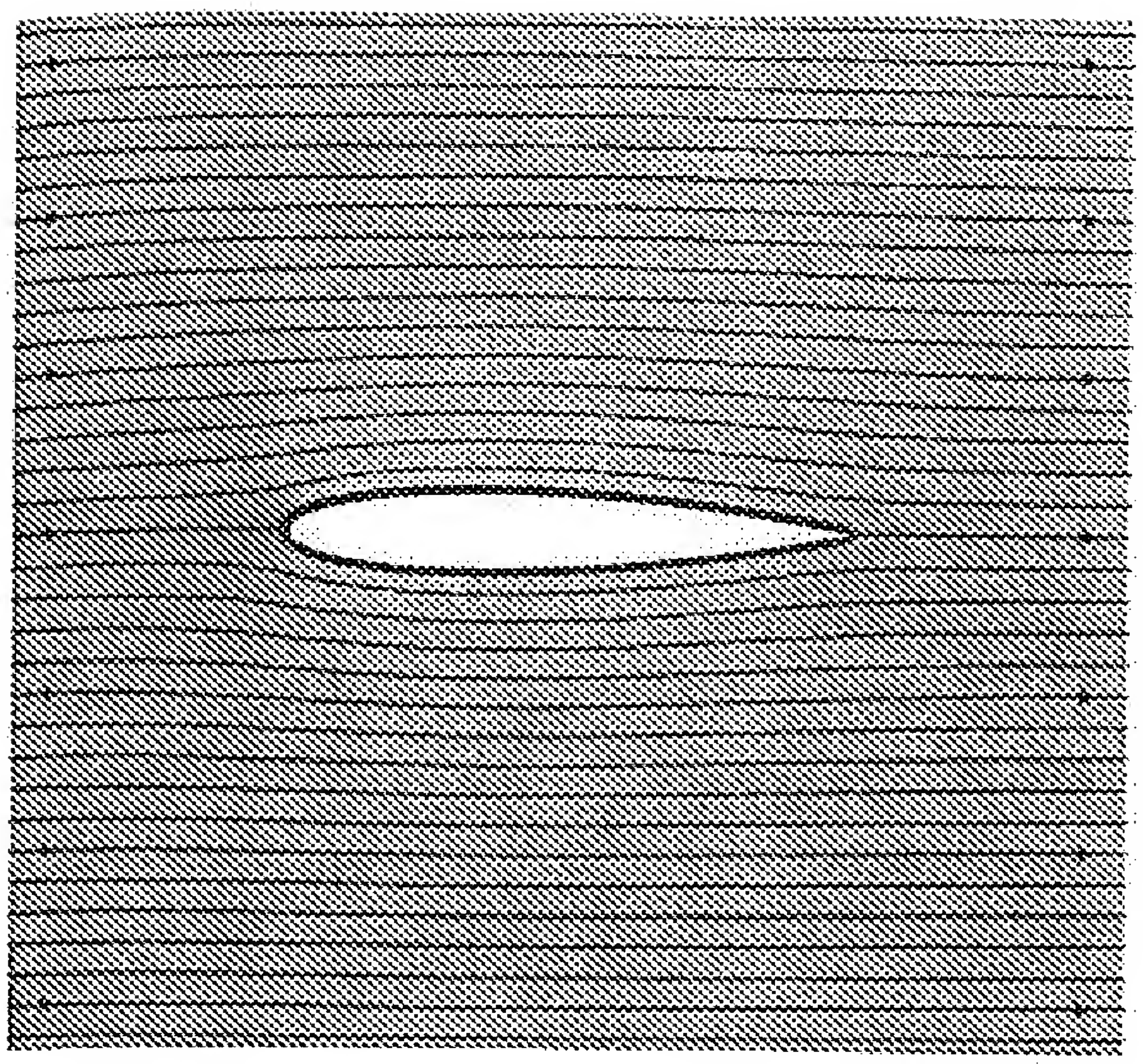

Fig. 6.3.1 An airplane wing is a streamlined airfoil and the airflow around it is laminar. This horizontal wing is symmetric, top and bottom, and the airflow splits evenly into airstreams above and below it. Since it doesn't deflect the airflow, it experiences no lift.

Although the wing's near lack of air resistance should surprise you, you probably take it for granted. That's because you've often observed that such "streamlined" objects cut through the air particularly well. Having a long, tapered tail allows the wing to avoid the flow separation and turbulent wake that occur behind an unstreamlined ball.

What makes the horizontal wing streamlined is the extremely gradual rise in air pressure after its widest point. While this gently rising pressure pushes the wing's boundary layer backward, opposite the direction of flow, the force it exerts is so weak that the layer doesn't stall. Driven onward by viscous forces from the freely flowing airstream, the wing's boundary layer manages to keep moving forward all the way to the wing's trailing edge and never triggers flow separation. The wing produces almost no turbulent wake and experiences almost no pressure drag.

Airplane Wings: Producing Lift

With so little air resistance, the airplane accelerates forward rapidly and soon reaches takeoff speed. The pilot then raises the airplane's nose so that its wings are no longer horizontal and they begin to experience upward lift forces. The airplane's total lift soon exceeds its weight and it begins to accelerate upward into the air. The airplane is flying!

But let's take a closer look at the moment of takeoff. If you could see the airflow and were paying close attention, you'd notice a remarkable sequence of events that begins when the wings tilt upward.

At first, the airflow around the tilted wings continues to travel horizontally on average, although it develops a peculiar shape (Fig. 6.3.2*a*). The two airstreams, one over the tilted wing and one under it, each bend twice—once up and once down. As we saw while studying balls, when an airstream bends toward the wing, the pressure near the wing is below atmospheric and when an airstream bends away from the wing, the pressure near the wing is above atmospheric. Since each airstream bends equally toward and away from the wing, it experiences no overall deflection or average pressure change and provides the wing with no overall lift.

But the lower airstream is making a sharp bend around the wing's trailing edge, essentially an upward kink. Air's inertia makes such a kink unstable and it soon blows away from the wing's trailing edge as a swirling horizontal vortex of air (Fig. 6.3.2*b*). After shedding that vortex, the wing establishes a new, stable flow pattern in which both airstreams pass smoothly away from the wing's trailing edge

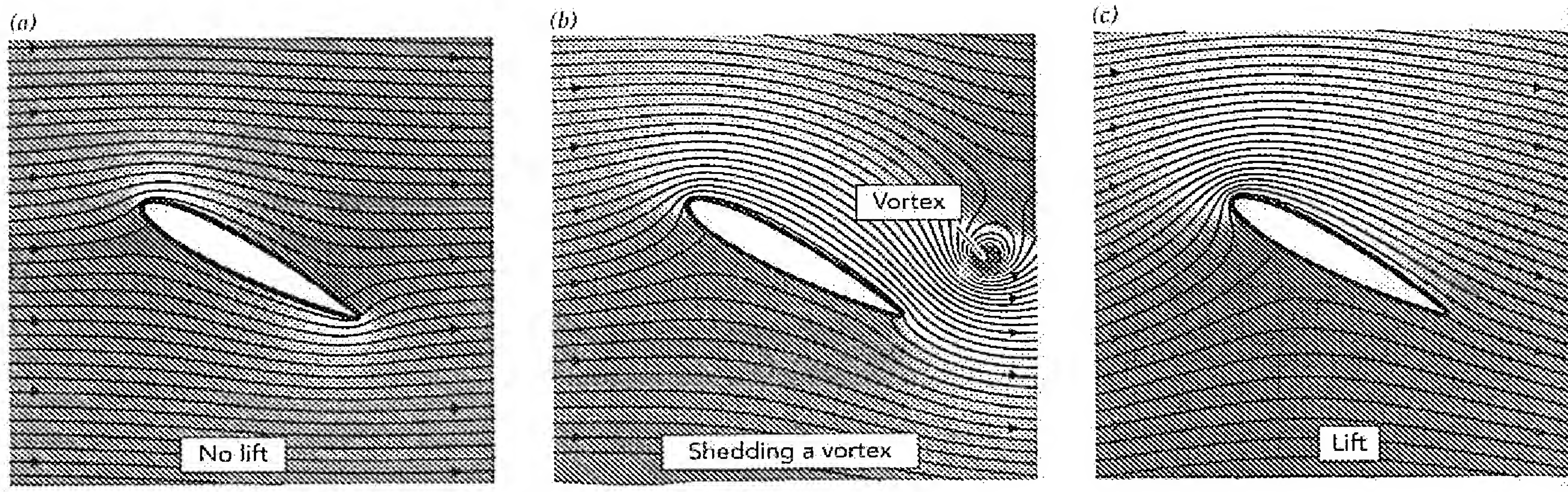

Fig. 6.3.2 (*a*) Although this wing's leading edge has been tipped upward, giving it a positive angle of attack, the airflow around it is relatively symmetric and produces no lift. (b) The kink at the trailing edge of the wing is unstable and is blown away or shed as a horizontal vortex. (c) The resulting airflow is deflected downward and the wing experiences an upward lift force.

(Fig. 6.3.2*c*), a situation named the Kutta condition after the German mathematician M. Wilhelm Kutta (1867–1944).

In this new pattern, the airstream flowing over the wing is longer than the airstream flowing under it and both bend downward (Fig. 6.3.3). The upper airstream bends primarily toward the wing, so the air's pressure just above the wing is below atmospheric (a shift toward light shading) and its speed is increased (narrowly spaced streamlines). In contrast, the lower airstream bends primarily away from the wing, so the air's pressure just below the wing is above atmospheric (a shift toward dark shading) and its speed is decreased (widely spaced streamlines). The air pressure is now higher under the wing than over it, so this new flow pattern produces upward lift. The air now supports your plane and up you go.

Another way to think about this lift is as a deflection of the airflow. Air approaches the wing horizontally but leaves it heading somewhat downward. To cause this deflection, the wing must push the airflow downward. In reaction, the airflow pushes the wing upward and produces lift. In other words, the wing transfers downward momentum to the air and is left with upward momentum as a result. These two explanations for lift—the Bernoullian view that lift is caused by a pressure difference above and below the wing and the Newtonian view that lift is caused by a transfer of momentum to the air—are perfectly equivalent and equally valid.

However, the overall aerodynamic force on the wing isn't quite perpendicular to the onrushing air; it tilts slightly downwind. The perpendicular component of this aerodynamic force is lift, but the downwind component is a new type of drag force—induced drag. Induced drag is a consequence of energy conservation: in addition to transferring momentum to the passing air, the wing also transfers some energy to it. The air extracts that energy from the wing by pushing the wing downwind with induced drag and thereby doing negative work on it. Since induced drag is undesirable, the airplane minimizes it by using as much air mass as possible to obtain its lift. A larger mass of air carries away the airplane's unwanted downward momentum while moving downward less quickly and with less kinetic energy. Since larger wings obtain their lift from larger air masses, they experience less induced drag.

Unfortunately, larger wings also have more surface area and experience more viscous drag, so bigger isn't always better. And because wing shape and airspeed affect aerodynamic forces, too, wings must be carefully matched to their airplanes. Small propeller airplanes that move slowly through the air need relatively large,

How Airplanes Fly

As mentioned in the introduction of this book, a great deal of false concepts and "mythology" have built up around the principles of flight. In this chapter we explain with simple logical discussions the physical phenomena of lift and address some of the errors in the present explanations. Armed with an understanding of lift, we take it further and give you an intuitive understanding of flight in a much broader sense. We start by looking at three descriptions of lift.

The Popular Description of Lift

Most of us have been taught what we will call the "popular description of lift," which fixates on the shape of a wing. The key point of the popular description of lift is that the air accelerates over the top of the wing. Because of the Bernoulli effect, which relates the speed of the air to the static pressure, a reduced static pressure is produced above the wing, creating lift. The missing piece in the description is an understanding of the cause of the acceleration of the air over the top of the wing. A clever person contributed this piece with the introduction of the "principle of equal transit times," which states that the air that separates at the leading edge of the wing must rejoin at the

Daniel Bernoulli did not derive the "Bernoulli equation." His friend Leonid Euler did.

trailing edge. Since the wing has a hump on the top, the air going over the top travels farther. Thus it must go faster to rejoin at the trailing edge. The description is complete.

This is a tidy explanation and it is easy to understand. But one way to judge an explanation is to see how general it is. Here one starts to encounter some troubles. If this description gives us a true understanding of lift, how do airplanes fly inverted? How do symmetric wings (the same shape on the top and the bottom) fly? How does a wing flying at a constant speed adjust for changes in load, such as in a steep turn or as fuel is consumed? One is given more questions than answers by the popular description of lift.

One might also ask if the numbers calculated by the popular description really work. Let us look at an example. Take a Cessna 172, which is a popular, high-winged, four-seat airplane. The wings must lift 2300 lb (1045 kg) at its maximum flying weight. The path length for the air over the top of the wing is only about 1.5 percent greater than the length under the wing. Using the popular description of lift, the wing would develop only about 2 percent of the needed lift at 65 mi/h (104 km/h), which is "slow flight" for this airplane. In fact, the calculations say that the minimum speed for this wing to develop sufficient lift is over 400 mi/h (640 km/h). If one works the problem the other way and asks what the difference in path length would have to be for the popular description to account for lift in slow flight, the answer would be 50 percent. The thickness of the wing would be almost the same as the chord length.

Though enthusiastically taught, there is clearly something seriously wrong with the popular description of lift. The first thing that is wrong is that the principle of equal transit times is not true for a wing with lift. It is true only for a wing without lift. Figure 2.1 shows a computer simulation of the airflow around a wing. Periodically simulated smoke has been introduced to show the changes in the speed of the airflow.

The principle of equal transit times is not true for a wing with lift.

The first thing to notice is that the air going over the top of the wing reaches the trailing edge before the air that goes under the wing. In fact, the air that passed under the wing has a somewhat retarded velocity compared to the velocity of air some distance from the wing. Without the principle of equal

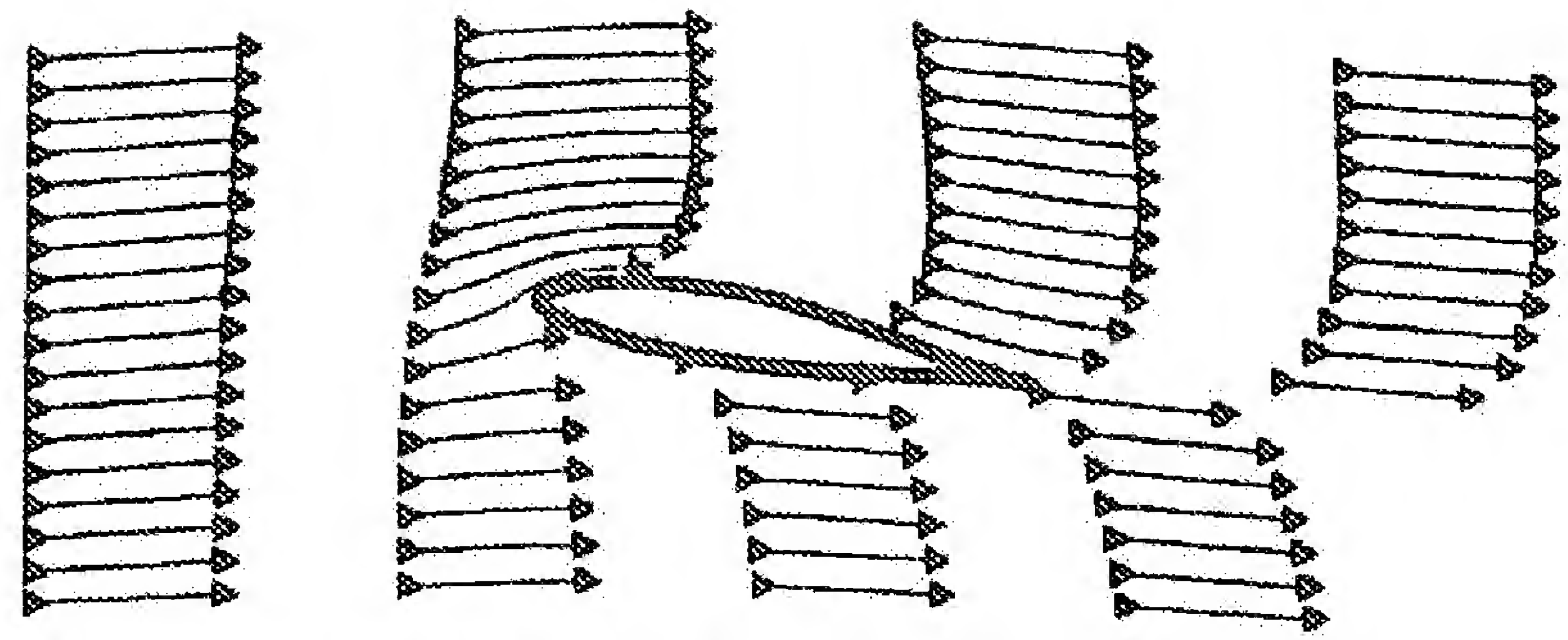

Fig. 2.1. Simulated smoke flowing around an airfoil.

transit times, the popular description of lift loses its explanation for acceleration of the air over the top of the wing.

In explaining the physics of the lift on the wing, we will reveal other problems with this description. But first we would like to introduce two other descriptions of lift. These are the "mathematical description of lift" and the "physical description of lift" The latter is the description followed in this book.

The Mathematical Description of Lift

Aeronautical engineers use the mathematical description of lift, a name coined for the sake of this discussion. It uses complex mathematics and computer simulations, and is a powerful design tool. Typically, the velocities of the air around the wing are generated with a computer program. Then, using Bernoulli's equation, the pressures and lift forces are accurately calculated. Since this description often calculates the lift of a wing from the acceleration of the air, this description has quite a bit in common with the popular description of lift.

The aeronautical engineers know that the principle of equal transit times is not true. They often use a mathematical concept called *circulation* to calculate the acceleration of the air over the wing. Circulation is a measure of the apparent rotation of the air around the wing. In the mathematical description of lift circulation is used to